

# PRELIMINARY SIMULATION OF POND-AQUIFER FLOW AND WATER AVAILABILITY AT A SEEPAGE POND NEAR BRUNSWICK, GEORGIA

Malek Abu-Ruman<sup>1/</sup> and John S. Clarke<sup>2/</sup>

**AUTHORS:** <sup>1/</sup> PhD Student, Georgia Institute of Technology, Atlanta, GA; <sup>2/</sup>Hydrologist, U.S. Geological Survey, 3039 Amwiler Road, Suite 130, Peachtree Business Center, Atlanta, GA 30360-2824.

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## INTRODUCTION

The Upper Floridan aquifer is the principal source of water in coastal Georgia, but declining water levels and local saltwater contamination have resulted in restricted withdrawals from the aquifer in some areas, and prompted interest in developing supplemental sources of ground water. In the coastal area, seepage ponds are sometimes constructed at golf courses, farms, or communities by excavating through sandy surface soils until the water table is reached. These ponds commonly are used to supply water for irrigation; however, the water-supply potential of such ponds is poorly understood.

To better define the water-supply potential of seepage ponds, the U.S. Geological Survey (USGS) in cooperation with the Georgia Department of Natural Resources, Environmental Protection Division, is evaluating ground-water flow in the vicinity of two seepage ponds in coastal Georgia. Ground-water-flow models are being developed to better understand pond-aquifer flow. This paper describes results of preliminary simulations at a seepage pond at Brunswick, Ga.

### Study Area

The study pond described herein is a 3-acre pond located on the campus of Coastal Georgia Community College, at Brunswick, Georgia (fig. 1). The study pond was excavated about 30 years ago to about 15 feet (ft) below sea level into the upper part of a fine-grained quartz sand layer that is part of the surficial aquifer (fig. 2). The surficial aquifer is underlain by a dense clay layer at a depth of about 40 ft below sea level. The pond is isolated from streams and drainage structures.

The surficial aquifer is recharged by rainfall in the vicinity of the pond. Ground-water flow generally is northwest to southeast toward Cyprus Mill Creek, part of a major estuary system about 2,500 ft east of the pond. Ground water seeps into the pond from the west-northwest and seeps out of the pond to the east-southeast.

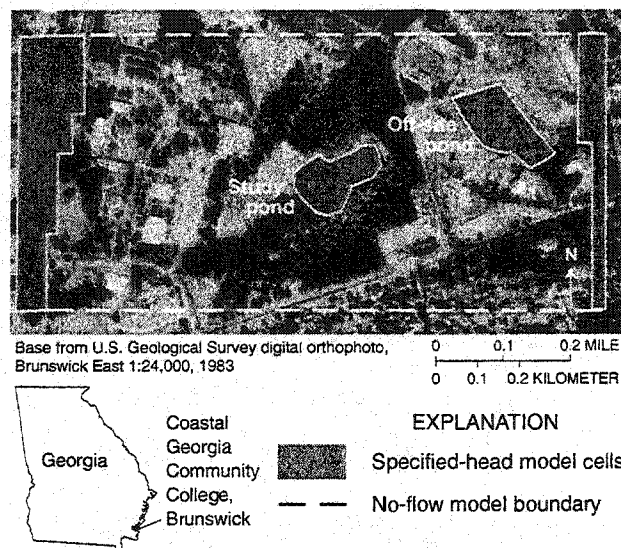


Figure 1. Location of study area and model boundaries.

### Ground-Water Seepage

Ground-water inflow (seepage) to the pond results from hydraulic gradients from the aquifer toward the pond. The following relation (Darcy's Law) applies:

$$Q = K I A \quad (1)$$

where

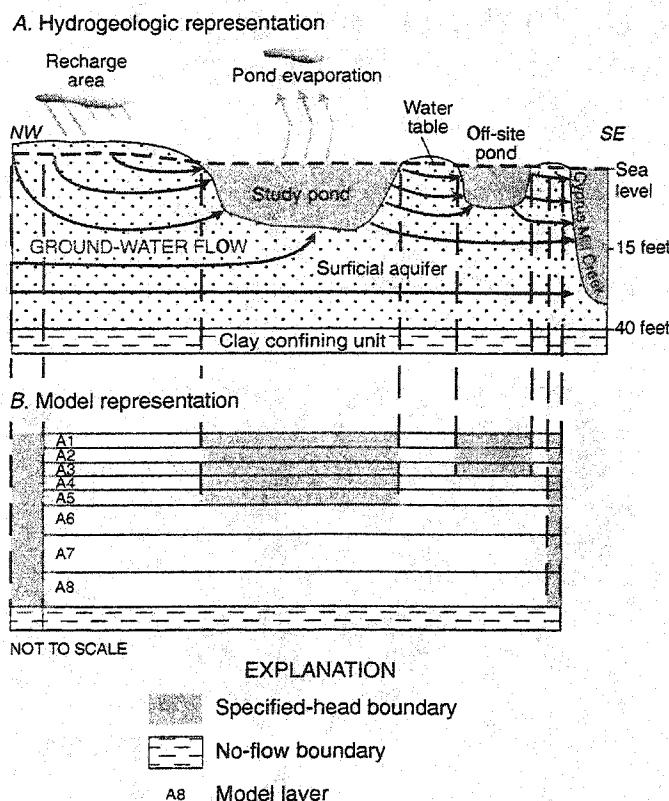
$Q$  = the seepage rate in ft<sup>3</sup>/day;

$K$  = the hydraulic conductivity in ft/d;

$I$  = the hydraulic gradient in ft/ft; and

$A$  = is the cross-sectional area in ft<sup>2</sup>.

Hydraulic conductivity is a constant; both hydraulic gradient and cross-sectional area may change as pond stage or ground-water level changes. Under non-pumping conditions, the regional hydraulic gradient is toward the western and northern shore of the pond, and away from the pond along the southern and eastern shore. Under pumping conditions, a depression in the water-table surface develops, and ground water flows toward the pond from all shorelines.



**Figure 2. Diagram showing (A) hydrogeologic framework and pond-aquifer flow, and (B) model layers and boundary conditions for the Coastal Georgia Community College pond-site model.**

Seepage represents ground water either entering or leaving the pond. When positive, more ground water enters than leaves the pond; when negative, more water leaves than enters the pond. Ground-water seepage can be estimated using the following volumetric relation:

$$\text{Seepage} = \text{Change in stage} + \text{Pumping} - \text{Precipitation} + \text{Evaporation} + \text{Transpiration} \quad (2)$$

Data from a continuous-monitoring weather station at the site provided information on precipitation and evaporation (transpiration was not considered).

During a 33-hr pumping test in May 2000, pond stage was lowered 2 ft by pumping at an average rate of 1,000 gallons per minute (gal/min). During the same period, there was no precipitation, estimated evaporation was about (10 gal/min), and transpiration was unknown. Thus, changes in pond stage during the pumping test mainly are due to the volume of water removed by pumping and contributed by ground-water seepage. Seepage estimates are limited by the accuracy of evaporation and transpiration estimates, and to pond-volume estimates determined using pond-stage and bathymetric data. Because transpiration is unknown, seepage estimates derived for the pond are lower than actual rates.

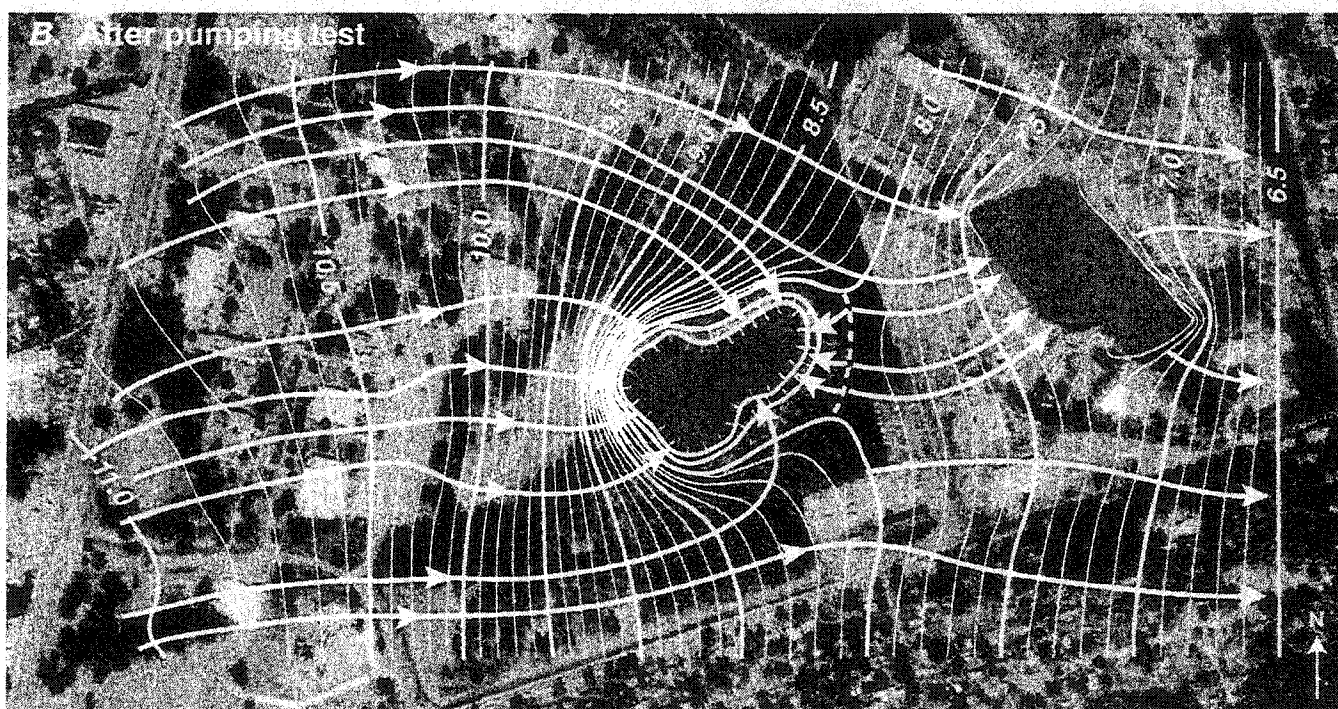
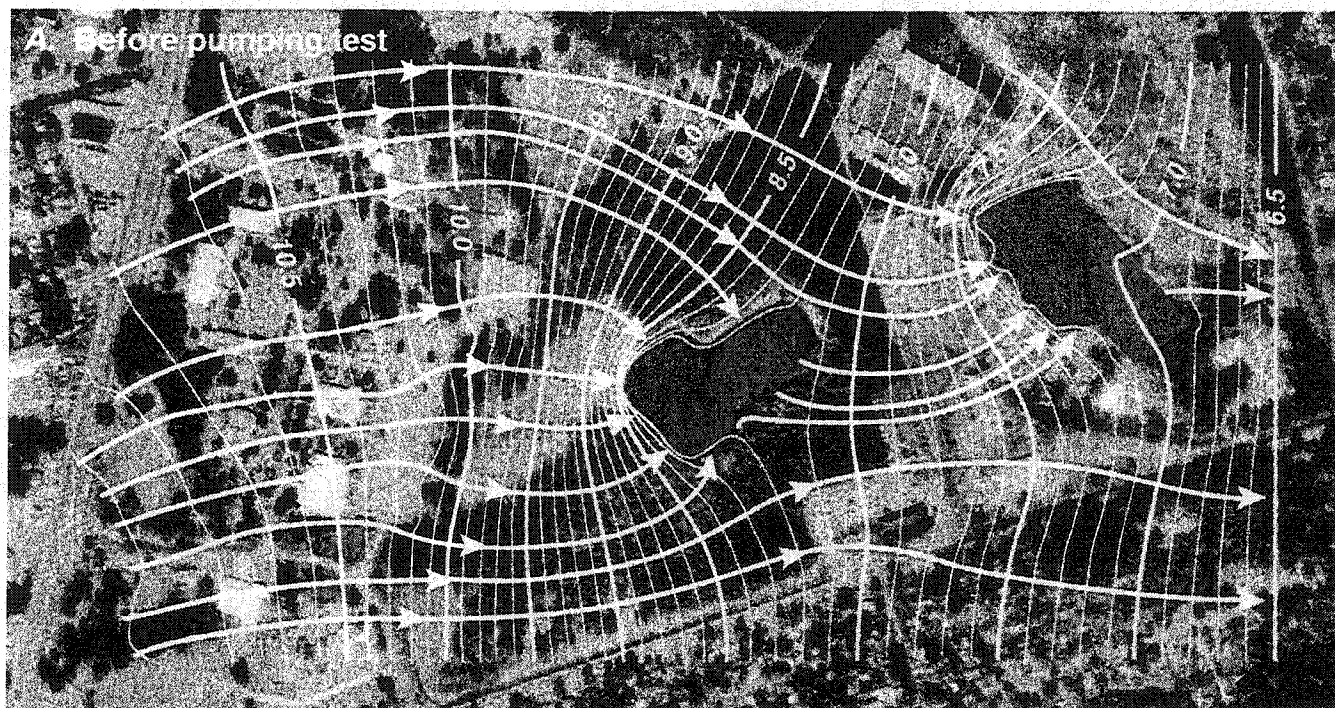
Rates of ground-water seepage vary depending on pond stage and related changes in hydraulic gradient and cross-sectional area. Decreasing pond stage results in an increased hydraulic gradient toward the pond and increased rates of seepage to the pond. During the pumping test, however, estimated seepage was about -280 gal/min, indicating a losing condition. This discrepancy results from errors in pond-volume and evaporation estimates, and from a lack of transpiration data. Following the pumping test, pond stage recovered about 0.1 ft in 25.5 hours corresponding to rate of about 90 gallons per minute gal/min, which combined with the estimated evaporation rate of 10 gal/min, equals a seepage rate of 100 gal/min.

### Preliminary Simulation of Pond-Aquifer Flow

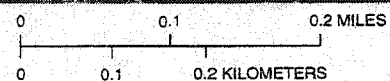
Pond-aquifer flow is being simulated using the USGS digital, three-dimensional, finite-difference ground-water flow model—MODFLOW (McDonald and Harbaugh, 1988). Steady-state and transient simulations are being used to evaluate changes in ground-water level and seepage to and from the pond prior to, and during the 33-hr pumping test. Initial conditions are simulated as steady state, followed by simulation of transient changes in recharge, pond stage, ground-water levels, and seepage.

The model consists of a variably spaced grid having 75 rows and 106 columns, encompassing an area of 0.4 square mile. Cell size ranges from 20 by 20 ft near the pond, to 100 by 120 ft at the outer margins of the model grid. Smaller cell sizes were used near the pond to better simulate steeper hydraulic gradients. In the model, the surficial aquifer is divided into eight layers—layer A1 is simulated as a water-table layer, whereas layers A2–A8 are simulated as confined layers (fig. 2).

Initial estimates of horizontal hydraulic conductivity (Kh) are within estimated ranges for a silty sand and are near values derived from aquifer-test data (Gregory Schultz and Carolyn Ruppel, Georgia Institute of Technology, written commun., 2000) at Sapelo Island, about 20 miles north of the site, but in a similar geologic setting. Initial Kh values range from 30 to 60 feet per day (ft/d). Vertical hydraulic conductivity (Kv) was assigned an initial value of 20 ft/d, which is about 1.5 to 3 times less than horizontal values. Pond bed sediments occur mostly in layer A6, and were assigned an initial value of 30 ft/d, or a vertical to horizontal ratio of 1:1. The uppermost layer (A1), simulated under water-table conditions, was assigned a specific yield of 0.04. Layers A2–A8, simulated as confined layers, were assigned a specific storage of 0.0003. Hydraulic property values are being adjusted as part of the calibration process.



Base from U.S. Geological Survey digital orthophoto, Brunswick East 1:24,000, 1983



#### EXPLANATION

— 10.5 — SIMULATED WATER-TABLE  
CONTOUR—Shows altitude of water  
table in surficial aquifer. Hachures  
indicate depression. Contour interval 0.1  
and 0.5 feet. Datum is sea level

→ DIRECTION OF GROUND-WATER FLOW  
- - - - GROUND-WATER DIVIDE

**Figure 3. Simulated water-table contours in the surficial aquifer (A) before pumping test on May 1, 2000 and (B) after the pumping test on May 3, 2000.**

The study pond is simulated as a constant-head boundary in the first five layers of the model. The depth and geometry of the pond bottom was determined from a bathymetric survey conducted during summer 1999. Pond-stage changes recorded by a continuous gage were applied to each stress period of the transient model. A second pond, located about 750 ft east of the study pond, is simulated as a constant-head boundary in the first three layers of the model.

Lateral boundary conditions for the model were selected to coincide as closely as possible with natural no-flow boundaries (figs. 1 and 2). No-flow boundaries are assigned to the northern and southern sides of the model and correspond to flow lines in the surficial aquifer. The eastern and western boundaries are simulated as specified head layers located at least 0.3 mile from the pond site to minimize influence on simulation results. The base of the model (layer A8) is bounded by a no-flow boundary at the top of the basal clay layer.

Recharge applied to the uppermost layer of the model for the initial steady-state simulation ranges from zero in the vicinity of impermeable surfaces such as parking lots, to 0.03 ft/d in unlined drainage ditches adjacent to impervious surfaces. Because there was no rainfall during the pumping test, recharge was zero during the transient simulation.

For the initial steady-state simulation of pre-test conditions, ground-water flow directions are from the western boundary and into the pond along the western and northern shores (fig. 3A). Ground water seeps from the pond along the southeastern shoreline. Some water moving from the pond seeps into the second pond site, with the remaining water moving toward Cyprus Mill Creek, east of the simulated area. These flow patterns compare favorably to water-table maps derived from test-well data.

Following the initial steady-state simulation, the model was discretized into one stress period divided into 33 time steps of one-hour duration for simulation of transient conditions. A map showing the preliminary simulated water table after 33 hours of pumping is shown in figure 3B. The simulated water table indicates a depression surrounding the study pond, with a steepened hydraulic gradient that captures flow along all shorelines. This depression resulted in the development of a ground-water divide between the study pond and the off-site pond located east of the site. Simulated flow is similar to that shown on water-table maps derived from test-well data.

## Water Availability

Ground-water seepage rates control the availability of water in the pond. Seepage rates vary in response to changes in hydraulic gradient and pond area. Availability of water supplies from seepage ponds in coastal Georgia is constrained by the fact that water flowing into the pond is derived from a water-table aquifer and, thus, is highly dependent on climatic conditions. Any water removed from the water table is lost from ground-water storage until replenished by rainfall recharging the aquifer. Because seepage ponds are used largely for irrigation during the dry season, the quantity of water available is limited by ground-water seepage and the size of the reservoir (pond storage) during dry periods. This limitation is demonstrated at the study pond by the time required for water levels to recover from the pumping test. For several weeks following the pumping test, water levels in wells surrounding the pond continued to decline, and remained low until rainfall recharged the aquifer; during the same period, the pond stage showed a similar pattern.

## DISCUSSION

Model results presented in this paper are preliminary and subject to change pending final calibration and sensitivity testing. Calibration will consist of adjusting hydraulic properties and boundary conditions to provide improved matches of hydraulic head and ground-water seepage. The calibrated model will be used to estimate the rate of ground-water seepage into the pond under varying stage observed before and during the 33-hour pumping test.

## REFERENCE CITED

- McDonald, M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 6, Chap. A1, 586 p.